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(71) Applicant : **FIRST PACIFIC NETWORKS, INC.**
871 Fox Lane
San Jose, California 95131 (US)

(72) Inventor : **McNamara, Robert P.**
836 Tatra Court
San Jose, California 95136 (US)

Inventor : **Amar, Amar Chand**
645 Chardonnay Drive
Fremont, California 94539 (US)
Inventor : **Balla, Prabhakara Chowdary**
509-243 Buena Vista Avenue
Sunnyvale, California 94086 (US)
Inventor : **Pon, Hung Cheung**
883 Humewick Way
Sunnyvale, California 94087 (US)
Inventor : **Chao, Chuan-Lung**
1443 Chavez Way
San Jose, California 95131 (US)
Inventor : **Wang, Chongzhen**
300 Winding Way
San Francisco, California 94112 (US)

(74) Representative : **Freeman, Jacqueline Carol**
W.P. THOMPSON & CO.
Celcon House
289-293 High Holborn
London WC1V 7HU (GB)

(54) **Extended range enhanced skew controller.**

(57) An apparatus and method for extending the range of a digital data network by enhancing skew control. The apparatus is a circuit for use in a network interface unit. The apparatus measures the distance of the network interface unit from the head-end retransmission unit of the network by transmitting a series of signal packets on the network and counting the time it takes for the packets to be received back at the interface unit. All transmissions on the network take place with reference to a timing mark transmitted by the head-end unit at a regular interval. The apparatus sends the first in the series of signal packets at a pre-determined pre-skew interval before the timing mark. The apparatus counts the number of clock cycles after the timing mark before the signal packet is received back at the network interface unit. If the signal packet is not received back at the network unit within a pre-determined number of clock cycles, the apparatus sends a new signal packet at a new, larger pre-skew interval before the timing mark and again counts the clock cycles after the timing mark. This process is repeated until a signal packet is successfully received back at the network interface unit. Once a signal packet is successfully received back at the network interface unit, the pre-skew value at which the packet was sent and the value of the number of clock cycles after the timing mark at which the packet was received

back is stored in the interface unit and all subsequent transmissions by that unit on the network are done at an interval before the timing mark defined by the stored skew value.

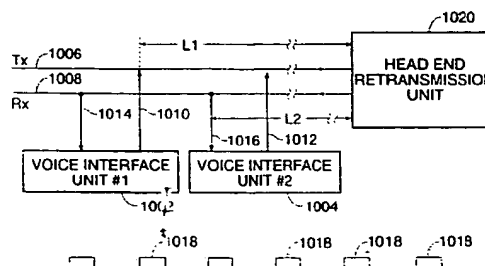


FIG. 4

The present invention relates generally to data communications networks and more specifically to an enhancement to network interface units in a high speed data interface network.

Modern data networks allow for the high speed transmission of digital data between multiple users. Such data might be digitized voice data in a private branch exchange (PBX) office telephone network, video data, or information data from digital information processing systems such as personal computers. Modern networks may allow for the transmissions of all three types of data over the same physical network cable.

One configuration for such a network is described in International Patent Application PCT/US89/01806, published as WO90/13956. This network is illustrated in Fig. 1, which is a block diagram of a digital data network of the type for which the invention is intended. It is characterized by a single network medium 12 connected to a plurality of network nodes, represented by Network Interface Units (NIUs) 20 each connected to a phone, computer, or other video, data or voice processing device (P) 22. The single medium is such that it can simultaneously carry a number of different signals, each in a different frequency band, thus allowing the network to have a number of frequency division multiplexed channels for carrying data. Each channel is further divided into two different frequency bands: a transmit frequency band and a receive frequency band. NIUs on the network transmit data on the transmit frequency and receive it on the receive frequency. A single head-end retransmission unit (HRU) 50 receives all data transmitted on the transmit frequency and retransmits it on the receive frequency for reception by all network nodes.

Fig. 2 is a diagram showing the time structure of signals on this network. Circuitry associated with the HRU provides a series of timing mark packets (TMs), transmitted simultaneously on all channels, at 1-ms intervals, thereby defining a series of 1-ms frames.

In one configuration of the network for which the present invention is designed, each frame consists of a 10-byte TM, a 71-byte (60 data bytes) signalling packet (SP), and 28 19.5-byte (16 data bytes) voice/data timeslots (VTSS), each capable of containing a voice/data packet (VP).

VPs are used to provide voice communication containing binary encoded (pulse code modulation - PCM) speech from a specific phone conversation or to provide data communication. They are transmitted every cycle during the course of a conversation. When transmitting voice, VPs contain no computer recognizable information. They are merely reconstructed into voice at the receiving node.

SPs are used for communications between nodes and contain computer recognizable information pertinent to the control of the network. Among the

functions of the SPs is the determination of skew intervals.

Each node is characterized by a skew time related to its physical position on the bus. Skew time refers to the different propagation delays resulting from the fact that the different nodes are at different distances from HRU 50. The nodes most remote from the HRU will receive the timing marks latest in time, and would, if they merely synchronized their transmissions to the timing mark, transmit relatively late compared to nodes nearer the HRU.

As a result of this skew time, there is a limit to the geographic range of the network. A typical maximum range in the prior art is about 5 km.

According to the invention, apparatus and method are provided for correcting for the different propagation delays in a bidirectional digital data network, thereby allowing a network of the type described to operate at a range of up to 80 km. The present invention is directed to a method and means whereupon each node determines its own skew time relative to other nodes. Each node, on power-up, transmits a series of signalling packets (SPs) upon receiving a timing mark and counts the number of clock cycles up to the width of the SP time period ($1/(5.018 \text{ MHz})$) until it receives the same SP (as retransmitted by the HRU). The first SP is transmitted at a pre-set pre-skew interval before the timing mark. If the SP is not received within the SP time period, the node increases the pre-skew interval and transmits a new SP. Once an SP is correctly received back at the node, the timing delay between transmission and reception is retained. This defines twice that node's skew time, and subsequent transmissions will be advanced by the skew time.

The invention will be understood upon reference to the following detailed description in connection with the remaining accompanying drawings, which are described by way of example, and in which:

Fig. 3 is a schematic block diagram of an enhanced skew controller according to the invention;

Fig. 4 is a schematic diagram illustrating the transmission time differences to the head-end retransmission unit;

Fig. 5 is a flow chart showing the determination of skew time.

Fig. 3 is a block diagram schematically showing the construction of an Extended Range Skew Controller 100 of the present invention. In the figure, numeral 1 designates a control unit which handles communication with the other circuitry of the NIU and generates control signals to each of the other components of the Extended Range Skew Controller. Operation of the control unit may be governed by firmware which is stored in a Read Only Memory (ROM) 2 or it may be a state machine as a matter of design choice. Skew register 3 is a 12-bit register divided into a low-

order 8-bit segment 5 and a high-order 4-bit segment 4. The control unit 1 can read data from both segments 4 and 5 of the register. The control unit 1 can also write data into high-order segment 4, but it cannot write into low-order segment 5 of the register. Counter 7 is an 8-bit counter which can count in a range of 0 to 255. Transmitter/receiver circuit 6 is for transmitting and receiving data packets over the network.

Fig. 4 shows a pair of NIUs 1002 and 1004. The upstream frequency band on the broadband cable is shown schematically as a transmission line 1006, with the downstream frequency band being shown as a receiving line 1008. It should be understood however that this is a schematic representation only. In the network being described both upstream and downstream transmissions take place over a single coaxial cable with the upstream portion of the signal being carried on a carrier different from the downstream portion. Each of NIUs 1002 and 1004 transmits in the upstream band (line 1006) as shown by arrows 1010, 1012. Similarly, each of NIUs 1002 and 1004 receives signals in a downstream frequency band (line 1008) as shown by arrows 1014, 1016. A series of timing marks 1018 which appear in the downstream frequency band are shown beneath line 1008 in Fig. 4.

As can be seen, NIU 1002 is a distance L_1 from HRU 1020, while NIU 1004 is a distance L_2 from HRU 1020. If NIU 1002 attempted to transmit in a timeslot defined to begin N microseconds after a timing mark 1018 by actually starting the transmission N microseconds after the timing mark is detected, the transmission would actually be received by NIU 1002 at a time $t(\text{skew})$ later. Time $t(\text{skew})$ is $(2 \cdot L_1 / C) + t_0$, where L_1 is the distance to HRU 1020, C is the speed of the signal on the transmission medium and t_0 is any delay incurred through the HRU. A transmission from NIU 1004, on the other hand, will be delayed by $(2 \cdot L_2 / C) + t_0$. Accordingly, data transmitted by NIU 1002 will actually fall farther behind timing mark 1018 than data transmitted by NIU 1004.

According to the present invention, each NIU, upon booting up, will determine its particular skew time by transmitting a series of skew signal packets (SSPs) and calculating the amount of time before it correctly receives back an SSP. This time then is designated as a skew time, and each data packet transmitted thereafter will be transmitted an amount of time equal to the skew time earlier than the time that the specified timeslot will be detected on receiving line 1008 at that particular NIU. For example, if a NIU determines a skew time of 38 microseconds, this represents a network of approximately 3 miles in radius (assuming a delay of 6.25 microseconds per mile for an electromagnetic wave in the coaxial medium).

Fig. 5 is a flowchart illustrating the operation of the Extended Range Skew Controller. When a NIU begins operation on the network, either after a reset

or on power-up (8), the control unit initiates skew determination by storing an initial pre-skew interval (9) in high-order part 4 of Skew Register 3. The control unit reads this initial pre-skew interval from the NIU. The initial pre-skew interval may be set by the user through software controlling the NIU based on the user's estimation of the distance of network node from the head-unit of the network. If no such estimation has been entered by the user, the initial pre-skew interval that the control unit stores in the high-order byte is 0. In an alternative embodiment, no provision is made for the user to set an initial pre-skew interval and the control unit sets an pre-skew interval based on a value stored in ROM 2.

Transmitting an SSP (10) occurs as follows: After storing the pre-skew interval, the control unit causes transmitter/receiver 6 to transmit an SSP and signals counter 7 to begin counting when the next timing mark is detected. The transmitter/receiver uses the pre-skew value stored in skew register 3 to determine when to send the SSP. The SSP is sent at a time interval before the next timing mark. The resultant time interval, as measured, is the pre-skew value stored in the skew register.

Once the SSP is transmitted, the transmitter/receiver waits for detection of timing pulse on the reception frequency of the network. When a timing pulse is detected (11) counter 7 begins counting (12). If a timing pulse is not detected, an error flag is set (13) which can be read by the NIU.

Counter 7 continues counting for the duration of the SP interval indicated in Fig. 2 or until the packet is received back at the transmitter/receiver after being retransmitted by the HRU (14). If the packet is received at the transmitter/receiver during the signal timing slot, the counter stops counting and stores its value in low-order part 5 of skew register 3 (15).

If the packet is not received before the end of the signal timing slot, counter 7 stops counting, resets itself (to zero), and signals the control unit that the signal packet was not received. The control unit then reads the pre-skew interval stored in high-order segment 4 to determine if the value is 15, which is the largest possible value that the 4-bit segment can hold (16). If the value in part 4 is less than 15, the control unit increments the value in segment 4 by 1 (17), and then signals the transmitter/receiver to transmit a signal packet with the new pre-skew interval (10). If the value is 15, then the controller waits a pseudo-random amount of time between 20 and 40 seconds and the entire operation is repeated, up to a total of 3 times. At the end of the third repetition, if no SSP has been correctly returned, the controller halts skew determination, removes the node from the network and an error is reported to the NIU (19).

All publications and other references or patent documents cited herein are incorporated by reference. It is to be understood that the above description

is intended to be illustrative and not restrictive. Many embodiments will be apparent to those skilled in the art upon reviewing the above description. The scope of the invention, therefore, should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

Claims

1. A method for determining skew interval in a long range digital network comprising the steps of:
 - transmitting a signalling packet at a user-set pre-skew interval prior to a timing pulse;
 - counting the number of clock cycles after the timing pulse until the signalling packet is returned; and
 - storing the sum of said counted clock cycles and said user-set pre-skew interval as the skew interval.
2. A method for determining the skew interval in a long range digital network comprising the steps of:
 - a) transmitting a signalling packet at a pre-skew interval prior to a timing clock; thereafter
 - b) counting the number of clock cycles after the timing clock until the signalling packet is returned;
 - c) if the packet is not returned within a predefined time period, increasing the pre-skew interval and then repeating steps a) and b) until the packet is returned during the predefined time period; and

upon the packet being returned during the predefined time period, storing the resultant sum of said counted value and said pre-skew interval as the skew interval.
3. An apparatus in a network interface unit for determining the skew interval in a long range digital network comprising:
 - means for storing a pre-skew interval based on geographical distance of said network interface unit from a headend unit of said digital network;
 - means coupled to said storing means for transmitting a signalling packet at said pre-skew interval prior to a timing clock signal;
 - receiving means for receiving said signalling packet;
 - counting means coupled to said receiving means for counting clock cycles following the timing clock signal until the signalling packet is returned;
 - controller means coupled to said counting

means and said storing means for detecting if said counting means has detected a received packet prior to elapse of a preset time period and, if said preset time period has not elapsed, for iteratively increasing the pre-skew interval and directing said transmitting means to retransmit the signalling packet until the counting means detects a received signalling packet within said predefined time period; and

storage means for storing the counter value indicative of the time a packet is returned during the predefined time period.

4. The apparatus according to claim 3 where said pre-skew interval is set by a user.
5. A circuit in a network interface unit for determining the skew interval in a long range digital network employing a central clock and central timing pulse signal comprising:
 - a skew register having a low-order part and a high-order part;
 - a network transmitter means coupled to said skew register for transmitting signal packets and data packets at a transmit time which is stored in said skew register, said transmit time being prior to said timing pulse;
 - a network receiver for receiving packets;
 - a counter coupled to said bus receiver and said skew register for counting the number of clock cycles which elapse between occurrence of timing pulse detection and receipt of a signalling packet by the network receiver and for storing said interval in said low-order part of said skew register; and
 - a controller coupled to said high-order part of said skew register, said transmitter and said counter for detecting when said counter has failed to detect a received packet in a predetermined time from said timing pulse, for increasing an interval stored in said high-order part of said skew register and for directing said transmitter to retransmit said signal packet at an increased pre-skew interval.

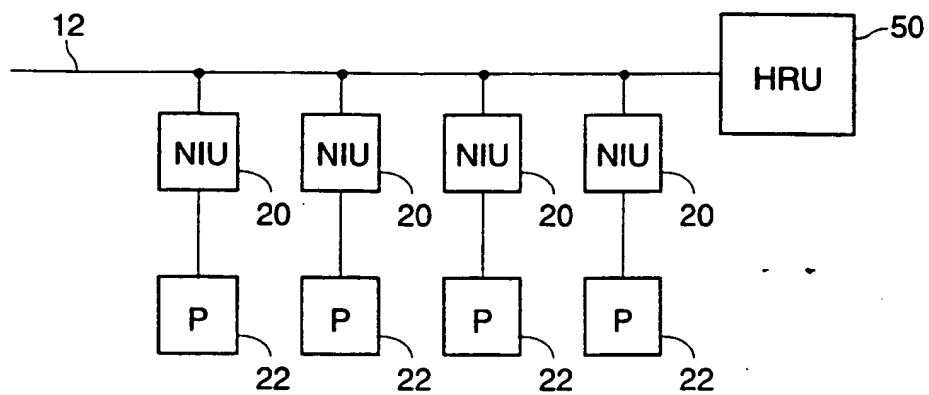


FIG. 1
PRIOR ART

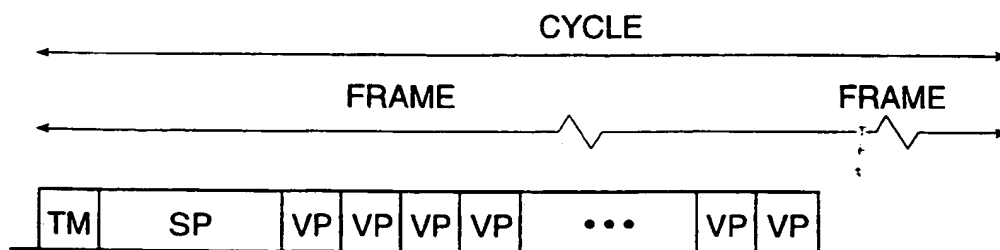


FIG. 2

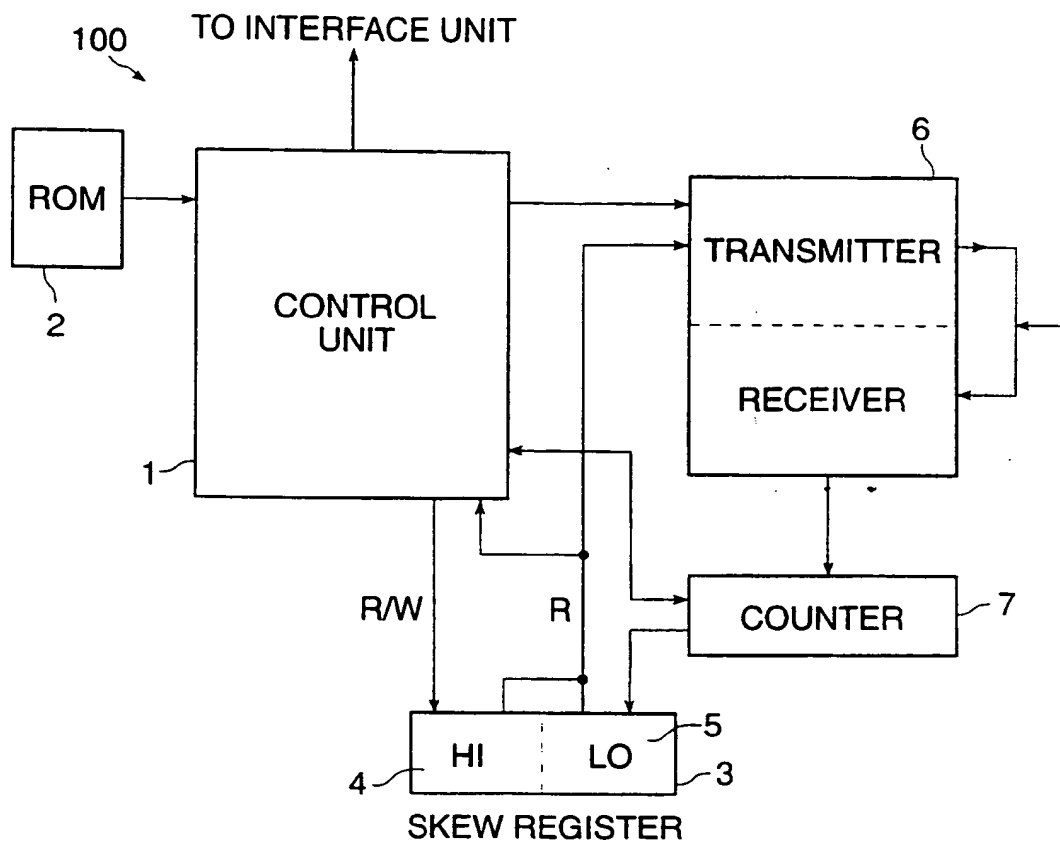


FIG. 3

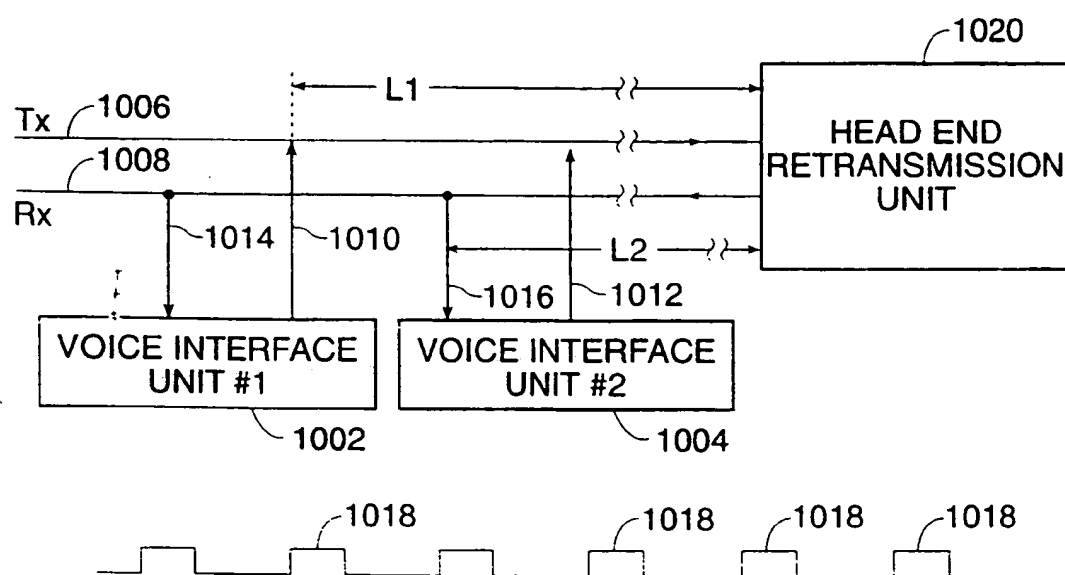
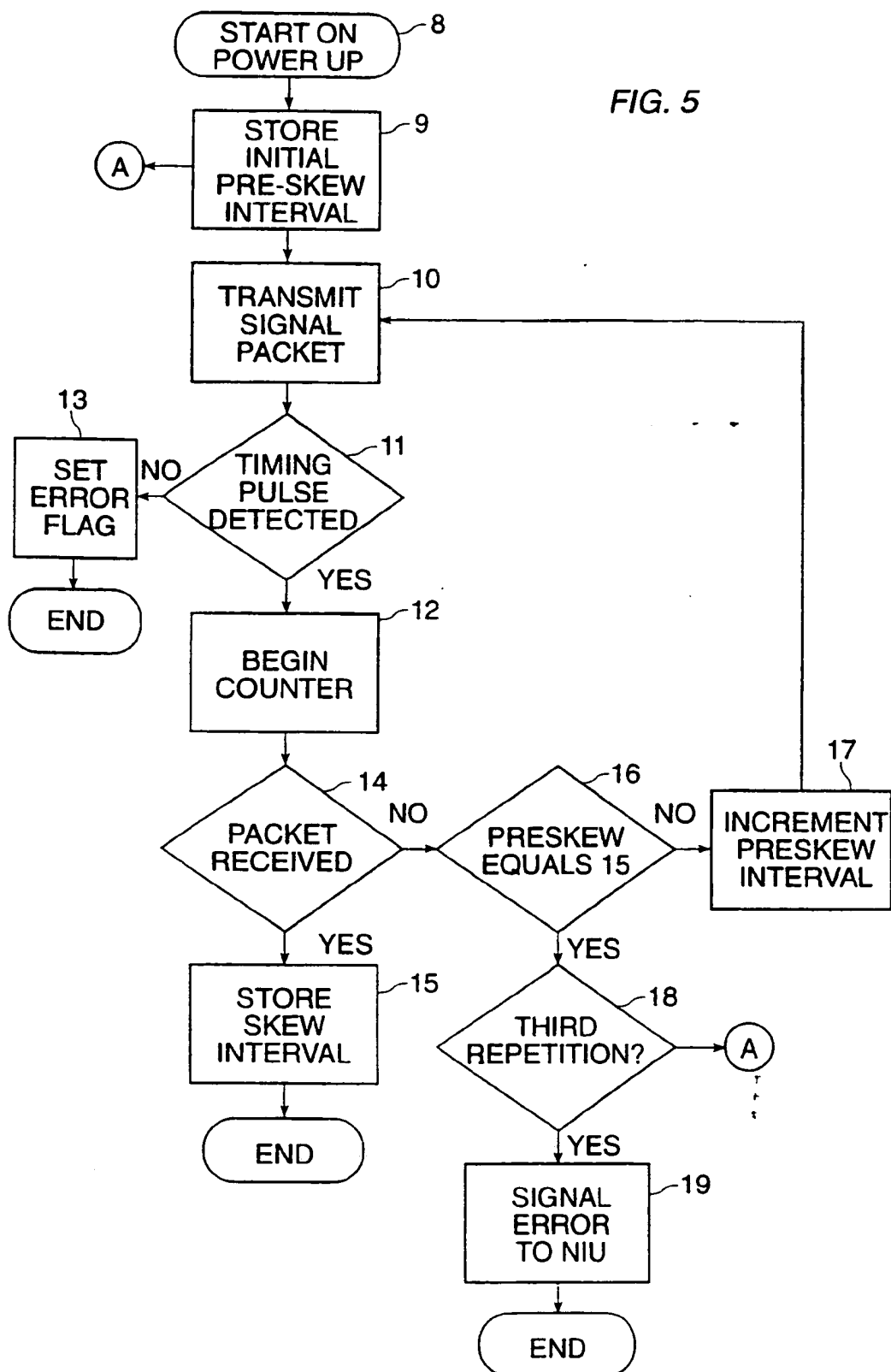


FIG. 4

FIG. 5





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(71) Applicant: **FIRST PACIFIC NETWORKS, INC.**
San Jose, California 95131 (US)

(72) Inventors:
• **McNamara, Robert P.**
San Jose, California 95136 (US)

- **Amar, Amar Chand**
Fremont, California 94539 (US)
- **Balla, Prabhakara Chowdary**
Sunnyvale, California 94086 (US)
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Sunnyvale, California 94087 (US)
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(74) Representative: **Freeman, Jacqueline Carol**
W.P. THOMPSON & CO.
Celcon House
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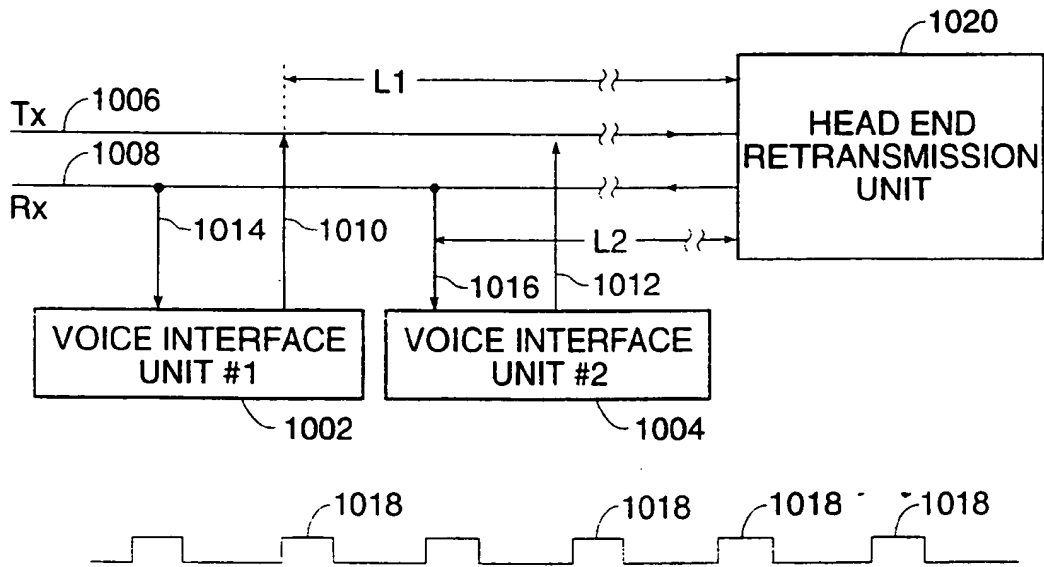


FIG. 4



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 2990

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	EP-A-0 334 569 (FIRST PACIFIC COMMUNICATIONS) 27 September 1989 * column 3, line 23 - line 47 * * column 6, line 34 - line 50 * * column 7, line 30 - line 47 * -----	1-5	H04L12/28 H04J3/06
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			H04L H04J
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 30 January 1996	Examiner Vaskimo, K
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone V : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document</p>			

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